

BUS INTERFACE TIMING ADJUSTMENT  
DEVICE, METHOD AND APPLICATION CHIP

CROSS-REFERENCE TO RELATED APPLICATION

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BACKGROUND OF THE INVENTION

Field of Invention

[0001] The present invention relates to a timing adjustment device and method. More particularly, the present invention relates to a bus interface timing adjustment device, method and application chip.

Description of Related Art

[0002] Due to increasing complexity of circuit boards, proper design of trace lines linking various devices and the processing of timing signals between different devices is increasingly difficult. In general, the chip manufacturer will provide necessary AC timing signals for synchronizing various devices on an integrated chip. However, due to difference in conditions of silicon chip manufacturing, trace layout or method of producing the printed circuit board (PCB), accuracy of the timing signal is often compromised.

[0003] Using the computer as an example, most computer systems are comprised of a central processing unit (CPU), a north bridge device and a south bridge device (the

north bridge device and the south bridge device together constitute a control chipset, or chipset in short). The central processing unit is coupled to the north bridge device. The north bridge device and the south bridge device are connected together through a high-speed bus. The north bridge device also exercises control over high-speed dynamic random access memory (DRAM). Principle function of the south bridge device includes controlling peripheral devices. The central processing unit and the north bridge device access data via a system bus. Similarly, the south bridge device and the north bridge device access each other's data through the control chipset bus. The north bridge device controls the high-speed dynamic random access memory through a memory bus. Hence, when the central processing unit and the north bridge device as well as the south bridge device and the north bridge device are conducting some data transactions, any mismatch in the trace line of circuit may lead to timing deviation. Serious timing deviation may result in data access errors and system instability. At present, however, most north bridge devices and south bridge devices have no special features for making timing and boost-signal driver adjustment. Thus, whenever there is a timing mismatch that results from a difference in chip property, printed circuit board layout and quality due to surface mount technology (SMT), trace lines for the circuit board must be re-routed again leading to an increase in production time and cost.

[0004] Furthermore, the clocking signal received by the memory of a computer system deviates according to the number of dual memory modules and the number of memory chips on the dual memory module plugged into the system. Hence, gauging the timing variation between the memory and the memory control device is very difficult. Because of this, the memory control device often has a register especially reserved for adjusting the timing at the memory interface. Yet, the adjusting value inside the register

is normally stored as a fixed value inside the basic input/output system (BIOS) and that value is difficult to change. To counteract differences due to manufacturing by various wafer manufacturers, differences due to bus layout on printed circuit boards and differences due to surface mount technologies, the adjusting value must be changed  
5 according to the actual conditions. This arrangement is not only cumbersome, but also leads to frequent inaccuracies. Another method is to provide a buffer to serve as an internal delay for clocking signal for adjusting the timing signals. However, this method can delay the phase of internal clocking signals only. Since there is no way to push the phase of the internal clocking signal forward, this method can have only limited accuracy.

#### SUMMARY OF THE INVENTION

[0005] Accordingly, one object of the present invention is to provide a timing adjustment device and method for a bus interface. Through repeated adjustment of the phase shift of bus interface clocking signal, a conduction of a read/write test of the bus  
15 interface and an inspection of the resulting read/write data to check for correctness, a range of phase shift in the bus interface clocking signal suitable for operating normally is determined. Thereafter, the phase shift value of the bus interface clock signal is set to a mid-value within the normal-operating phase shift range. In this way, data access by those devices linking with the bus is stabilized and the need for re-designing circuit layout  
20 or fabricating a new bus interface is avoided. Hence, production cost and some rework time is saved.

[0006] To achieve these and other advantages and in accordance with the object of the invention, as embodied and broadly described herein, the invention provides a timing adjustment device for a bus interface capable of preventing read/write errors due

to timing deviation in bus interface. The timing adjustment device includes a cycle protocol device, a special pattern device, an add/subtract device and a phase lock loop (PLL) device. The cycle protocol device generates special read/write cycle signals for linking any devices having connection with the bus interface. The phase lock loop device

5 is coupled to the bus interface for receiving an internal clocking signal. The internal clocking signal is phase-shifted to become a bus interface clock signal so that a special read/write test sample is sent to the bus and data is received back from the bus. The special pattern device is coupled to the cycle protocol device. According to the special read/write cycle signal generated by the cycle protocol device, the special read/write test sample is produced cyclically so that read/write test samples are repeatedly transferred to  
10 the bus interface and the resulting read/write data from the bus interface are checked for correctness. The add/subtract device is coupled to the phase lock loop device for adjusting and setting the phase shift in the clocking signal of the phase lock loop device. In addition, the phase lock loop device also receives a signal N for setting the phase shift  
15 resolution of the phase shift in the clocking signal of the phase lock loop device.

According to the inspection result of the special pattern device, this invention also carries out a computation to find the range of phase shift under which the clocking signal of the phase lock loop still operates normally. Degree of phase shift for the clocking signal of the phase lock loop device is set to the mid-value of the safety range.

20 [0007] This invention also provides a timing adjustment device for a system bus interface. The system bus interface couples with a system bus and the system bus couples with a central processing unit. The adjustment device includes a cycle protocol device, a special pattern device, an add/subtract device, a phase lock loop device and a core logic device.

[0008] In the process of adjusting the central processing bus interface and as a chipset begins to transmit data timing signals to the central processing unit, the core logic device will begin to assert a central processing unit reset signal to the central processing unit. Hence, the central processing unit is restarted. An add/subtract control signal is sent  
5 to the add/subtract device so that the add/subtract device increases or decreases phase adjusting signals accordingly.

[0009] In the process of adjusting the central processing bus interface and at the same time as the chipset begins to transmit data timing signals to the central processing unit, the cycle protocol device will generate special timing cycles and then outputs  
10 expected timing signals to the special pattern device. On receiving the expected timing signals, the special pattern device uses the special timing cycles to output special sample format signals to the system bus interface.

[0010] On receiving the phase adjusting signal and an internal clocking signal (CLK), the phase lock loop device shifts the internal clocking signal according to the  
15 phase adjusting signal. Thereafter, the phase lock loop device outputs the phase-shifted clocking signal to the system bus interface. The system bus interface utilizes the phase-shifted clocking signal as a timing signal to adjust the special sample format signal and drive the modified special sample format signal to the central processing unit.

[0011] The aforementioned operation is repeated a number of times. In this way,  
20 the core logic device is able to issue the central processing unit reset signal and add/subtract control signal repeatedly so that an optimum phase adjusting signal for the system bus interface is obtained.

[0012] This invention also provides a timing adjustment device for adjusting data timing signals sent from a central processing unit to a chipset. In the process of adjusting

the system bus interface and as the chipset receives data timing signals from the central processing unit, a core logic device will start to assert a central processing unit reset signal to the central processing unit. Hence, the central processing unit is restarted. An add/subtract control signal is sent to the add/subtract device so that the add/subtract  
5 device increases or decreases phase adjusting signals accordingly.

[0013] On receiving the phase adjusting signal and an internal clocking signal (CLK), a phase lock loop device shifts the internal clocking signal according to the phase adjusting signal. Thereafter, the phase lock loop device outputs the phase-shifted clocking signal to the system bus interface.

10 [0014] When the central processing unit is restarted, the central processing unit outputs a result signal to the system bus interface. The system bus interface utilizes the phase-shifted clocking signal to drive the result signal so that the system bus interface is able to output special sample format signals to a special pattern device.

[0015] In the process of adjusting the central processing bus interface and as the  
15 chipset begins to receive data from the central processing unit, the cycle protocol device will generate special timing cycles and then outputs expected timing signals to the special pattern device. The special pattern device receives the special sample format signal from the system bus interface during the special timing cycles.

[0016] The aforementioned operation is repeated a number of times. In this way,  
20 the core logic device is able to issue the central processing unit reset signal and the add/subtract control signal a number of times so that an optimum phase adjusting signal for the system bus interface is obtained.

[0017] This invention also provides a method for adjusting the timing relationship with a system bus interface. The method includes the following steps. A

central processing unit reset signal is asserted to a central processing unit and then an add/subtract control signal is asserted to increase/decrease a phase adjusting signal. An internal clocking signal is shifted according to the phase adjusting signal and the phase-shifted clocking signal is output. A special sample format signal is sent to the system bus interface according to a special timing cycle. On receiving the phase-shifted clocking signal and the special sample format signal, the system bus interface adjusts the special sample format signal and drives the modified special sample format signal to the system bus interface according to the phase-shifted clocking signal.

[0018] If the phase-shifted clocking signal produces sub-optimal results, the central processing unit reset signal and an add/subtract control signal for increasing/decreasing the phase-shift signal is issued again. The above steps are repeated until a phase-shift signal that permits the system bus interface to operate at an optimum condition is found.

[0019] This invention also provides a method for adjusting timing relationship with a system bus interface. The method includes the following steps. A central processing unit reset signal is asserted to a central processing unit and then a result signal is sent to the system bus interface. An add/subtract control signal is asserted to increase/decrease a phase adjusting signal. An internal clocking signal is shifted according to the phase adjusting signal and the phase-shifted clocking signal is output. On receiving the phase-shifted clocking signal and a special sample format signal, the system bus interface adjusts the special sample format signal and drives the modified special sample format signal to the system bus interface according to the phase-shifted clocking signal. At this stage, the special sample format signal from the system bus interface can be received according to special timing cycles. If the phase-shifted clocking

signal produces sub-optimal results, a central processing unit reset signal and an add/subtract control signal for increasing/decreasing the phase-shift signal is issued again. The above steps are repeated until a phase-shift signal that permits the system bus interface to operate at an optimum condition is found.

5 [0020] This invention also provides a control chipset that includes a first control chip and a second control chip connected via a bus. The first and the second control chips each have a chip bus interface for latching and buffering signals between the first and the second control chip. The first control chip further includes a timing adjustment device coupled to the chip bus interface within the first control chip for controlling the chip bus  
10 interface and adjusting the timing of the signals between the first control chip and the bus. The timing adjustment device includes a cycle protocol device, a special pattern device, an add/subtract device and a phase lock loop device. The second control chip further includes a special pattern comparator/generator.

[0021] In the process of adjusting the timing between the first control chip and the  
15 chip bus interface, the cycle protocol device generates a special timing cycle so that an expected timing signal is output. The special pattern device is coupled to the cycle protocol device and the chip bus interface of the first control chip for receiving the expected timing signal so that a special sample format signal is output to the chip bus interface of the first control chip during the special timing cycle. The add/subtract device  
20 serves to increase/decrease a phase adjusting signal. The phase lock loop device is coupled to the add/subtract device and the chip bus interface of the first control chip for receiving the phase adjusting signal and shifting an internal clocking signal. The phase lock loop device shifts the internal clocking signal according to the phase adjusting signal and then outputs a phase-shifted clocking signal. According to the phase-shifted clocking



signal, the chip bus interface of the first control chip is able to adjust the special sample format signal and drive the modified special sample format signal to the bus.

[0022] The special pattern comparator is coupled to the chip bus interface of the second control chip. In the process of adjusting the chip bus interface of the first control chip, the first control chip repeatedly increases/decreases the phase adjusting signal and asserts the changed phase adjusting signal. Consequently, the chip bus interface of the first control chip repeatedly adjusts the special sample format signal and drives the modified special sample format signal to the bus. Meanwhile, the chip bus interface of the second chip receives a signal from the bus and determines if the signal and the special sample format signal are identical or in error through the special pattern comparator. Ultimately, an optimal phase-shifting signal for operating the chip bus interface of the first control chip is obtained.

[0023] This invention also provides a method for adjusting the timing signals of a chip bus interface inside a first control chip. The chip bus interface is coupled to the bus and the bus is coupled to a second control chip. The second control chip includes a chip bus interface. The timing adjusting method includes the following steps. First, a phase adjusting signal is asserted to shift an internal clocking signal and then the phase-shifted clocking signal is output. According to a special timing cycle, a first special sample format signal is input into the chip bus interface of the first control chip. The chip bus interface of the first control chip adjusts the first special sample format signal and then drives the modified first special sample format signal to the bus according to the phase-shifted clocking signal. Thereafter, the chip bus interface of the second control chip receives signals on the bus and determines if the correct first special sample format signal is received. The phase adjusting signal is increased/decreased and then the modified

phase adjusting signal is asserted to find the optimum phase adjusting signal for operating the chip bus interface.

[0024] The aforementioned timing adjustment method mainly adjusts the timing signal for sending data from the first control chip to the second control chip. In a similar way, the adjustment of the timing signal for the transfer of data from the second control chip to the first control chip includes the following steps. According to a special timing cycle, the chip bus interface of the second control chip drives a second special sample format signal to the bus. Meanwhile, the chip bus interface of the first control chip adjusts and latches the signals on the bus according to the phase-shifted clocking signal. The first control chip conducts a comparison test to determine if the correct second special sample format signal is received.

[0025] This invention also provides a north bridge control chip coupled to a south bridge control chip through a bus. The north bridge control chip includes a chip bus interface and a timing adjustment device. The chip bus interface is coupled to the bus for latching and buffering the signals moving between the north bridge control chip and the south bridge control chip. The timing adjustment device is coupled to the chip bus interface for controlling the chip bus interface and adjusting the timing of the communication signals between the north bridge control chipset and the bus. The timing adjustment device of this invention at least includes a cycle protocol device, a special pattern device, an add/subtract device and a phase lock loop device.

[0026] The cycle protocol device generates a special timing cycle for outputting an expected timing signal when the timing signal at the chip bus interface of the north bridge control chip is adjusted. The special pattern device is coupled to the cycle protocol device and the chip bus interface of the north bridge control chip for receiving the

expected timing signal. Hence, a special sample format signal from the chip bus interface of the north bridge control chip is received during the special timing cycle. The add/subtract device increases/decreases a phase adjusting signal. The phase lock loop device is coupled to the add/subtract device and the chip bus interface of the north bridge control chip for receiving the phase adjusting signal and an internal clocking signal. The phase lock loop device shifts the internal clocking signal according to the phase adjusting signal and outputs a phase-shifted clocking signal. The chip bus interface of the north bridge control chip adjusts and drives the signal on the bus according to the phase-shifted clocking signal to produce the special sample format signal.

10 [0027] In the process of adjusting the chip bus interface of the north bridge control chip, the north bridge control chip repeatedly increases/decreases the phase adjusting signal and then asserts the changed phase adjusting signal. Hence, the chip bus interface of the north bridge control chip is able to adjust and drive the signal on the bus multiple times. According to the correctness of the special sample format signal received by the chip bus interface of the north bridge control chip, an optimal phase adjusting signal for operating the chip bus interface of the north bridge control chip is found.

[0028] This invention also provides a memory controller coupled to a memory bus. The memory bus is coupled to a memory unit. The memory controller includes a memory initialization device, a memory bus interface and a timing adjustment device.

20 The timing adjustment device further includes a cycle protocol device, a special pattern device, a first add/subtract device, a second add/subtract device, a first phase lock loop device and a second phase lock loop device.

[0029] The memory initialization device is coupled to the memory bus for initializing the memory unit. The memory unit must go through an initialization

procedure before the memory unit can operate normally. The memory bus interface is coupled to the memory bus for latching and buffering the communication signals between the memory controller and the memory unit. The timing adjustment device is coupled to the memory bus interface for controlling the memory bus interface and adjusting the timing of the communication signals between the memory controller and the memory bus.

[0030] The cycle protocol device within the timing adjustment device generates a special timing cycle for outputting an expected timing signal when adjusting the timing of the memory bus interface. The special pattern device is coupled to the cycle protocol device and the memory bus interface for receiving the expected timing signal from the cycle protocol device. Hence, in the special timing cycle, a first special sample format signal is sent to the memory bus interface and, in the meantime, a second special sample format signal is picked up from the memory bus interface.

[0031] The first and the second add/subtract device increase/decrease and generate a first and a second phase adjusting signal respectively. The first phase lock loop device is coupled to the first add/subtract device and the memory bus interface for receiving the first phase adjusting signal and an internal clocking signal. According to the first phase adjusting signal, the first phase lock loop device shifts the internal clocking signal to output a first phase-shifted clocking signal. The memory bus interface drives the first special sample format signal to the memory bus. According to the first phase-shifted clocking signal, the second phase lock loop device is coupled to the second add/subtract device and the memory bus interface for receiving the second phase adjusting signal and the internal clocking signal. The second phase lock loop device shifts the internal clocking signal to output a second phase-shifted clocking signal

according to the second phase adjusting signal. According to the second phase-shifted clocking signal, the memory bus interface adjusts and drives the signal on the memory bus to produce the second special sample format signal.

[0032] The first and the second add/subtract device repeatedly increase/decrease and assert the first phase adjusting signal and the second phase adjusting signal. Through a comparison of the received first special sample format signal and the second special sample format signal, an optimal phase adjusting signal for operating the memory bus interface is found.

[0033] This invention also provides a method for adjusting the timing of a memory controller. The memory controller has a memory bus interface coupled to a memory bus. The memory bus is coupled to a memory unit. The timing adjustment method includes the following steps. First, the memory unit is initialized and then a phase adjusting signal is issued. According to the phase adjusting signal, an internal clocking signal is shifted to produce a phase-shifted clocking signal. A first special sample format signal is input into the memory bus interface according to a special timing cycle. According to the phase-shifted clocking signal, the memory bus interface drives the first special sample format signal to the memory bus and then the memory bus interface receives the signal on the memory bus to generate a second special sample format signal. The second special sample format signal from the memory bus interface is received according to the special timing cycle. The first special sample format signal and the second special sample format signal are compared. Finally, the phase adjusting signal is increased/decreased and re-asserted a number of times to find the optimal phase adjusting signal for operating the memory bus interface.

[0034] The timing adjustment device and method for a bus interface according to this invention may eliminate system instability resulting from inappropriate layout design. Since there is no need to re-route a circuit board or re-fabricate a bus interface, production cost and some re-working time is saved.

5 [0035] It is to be understood that both the foregoing general description and the following detailed description are exemplary, and are intended to provide further explanation of the invention as claimed.

#### BRIEF DESCRIPTION OF THE DRAWINGS

10 The accompanying drawings are included to provide a further understanding of the invention, and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. In the drawings,

[0036] Fig. 1 is a schematic diagram showing a timing adjustment device for a  
15 system bus interface according to a first preferred embodiment of this invention;

[0037] Fig. 2 is a flow chart showing the steps for adjusting the timing of a system bus interface according to the first preferred embodiment of this invention;

[0038] Fig. 3 is a schematic diagram showing a control chipset connection system according to a second preferred embodiment of this invention;

20 [0039] Fig. 4 is a flow chart showing the steps for adjusting the control chipset connection system according to the second preferred embodiment of this invention;

[0040] Fig. 5 is a schematic diagram showing a memory controller according to a third preferred embodiment of this invention; and

[0041] Fig. 6 is a flow chart showing the steps for adjusting the timing of the memory controller according to the third preferred embodiment of this invention.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

5 [0042] Reference will now be made in detail to the present preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[0043] Fig. 1 is a schematic diagram showing a timing adjustment device for a  
10 system bus interface according to a first preferred embodiment of this invention. The system in Fig.1 mainly includes a timing adjustment device 100 and a system bus interface 101, both of which are incorporated inside a control chipset. The control chipset and a central processing unit 104 are connected together through a system bus 128.

[0044] The timing adjustment device 100 further includes a core logic device 102,  
15 two add/subtract devices 106 and 108, two phase lock loop devices 110 and 112, a special pattern device 122 and a cycle protocol device 120. The special pattern device 122 is coupled to the cycle protocol device 120 and the system bus interface 101. The phase lock loop device 110 is coupled to the add/subtract device 106 and the system bus interface 101. The phase lock loop device 112 is coupled to the add/subtract device 108  
20 and the system bus interface 101. The core logic device 102 is coupled to the central processing unit 104 and the pair of add/subtract devices 106 and 108.

[0045] The system bus interface 101 further includes two latching devices 114 and 118, two buffers 124 and 132 and a drive-boosting controller 126. The latching device 114 is coupled to the special pattern device 122 and the phase lock loop device 120.

The latching device 118 is coupled to the special pattern device 122 and the phase lock loop device 120. The buffer 124 couples with both the latching device 114 and the drive-boosting controller 126. The buffer 132 couples with the latching device 118.

[0046] In the process of adjusting the system bus interface 101 and as the chipset  
5 transmits timing signals to the central processing unit 104, the core logic device 102 will assert a central processing unit reset signal to the central processing unit 104. Thus, the central processing unit 104 is restarted. After restarting, the central processing unit 104 executes special command timing signals, for example, reading an instruction from a fixed address location. The special pattern device 122 asserts a series of no operation  
10 (NOP) instruction codes during a special timing cycle under the control of the cycle protocol device 120. Since the central processing unit 104 will continue to read instructions from the next address if the NOP instruction codes are received correctly, the special pattern device 122 may compare the result signals and determine if the currently set timing permits normal operation or not.

[0047] In the process of adjusting the system bus interface 101 and as the chipset  
15 transmits data timing signals to the central processing unit 104, the cycle protocol device 120 will generate a special timing cycle simultaneously and output an expected timing signal to the special pattern device 122. On receiving the expected timing signal, the special pattern device 122 outputs a special sample format signal to the latching device  
20 114 of the system bus interface 101 according to the special timing cycle. For example, the cycle protocol device 120 may set the special timing cycle to be two clock cycles and the special pattern device 122 will output the special sample format signal to the latching device 114 of the system bus interface 101 every two clock cycles.



[0048] On the other hand, the core logic device 102 will assert an add/subtract signal to the add/subtract device 106. On receiving the add/subtract signal, the add/subtract device 106 increases/decreases a phase adjusting signal according to the add/subtract signal.

5 [0049] When the phase lock loop device 110 receives the phase adjusting signal and an internal clocking signal, the phase lock loop device 110 shifts the internal clocking signal according to the phase adjusting signal and a signal N and then outputs a phase-shifted clocking signal to the latching device 114 of the system bus interface 101. The latching device 114 of the system bus interface 101 uses the phase-shifted clocking signal as a timing signal for adjusting the special sample format signal and driving the modified special sample format signal to the buffer 124. Here, signal N is a number that decides the magnitude of phase shift in the internal clocking signal in each phase shift operation. For example, if  $N = 3$ , the phase shift value = internal clocking signal/ $2^3$ . Hence, the phase-shifted clocking signal = internal clocking signal + internal clocking signal/ $2^3$ .

15 [0050] When the buffer 124 receives a new special sample format signal, the drive-boosting controller 126 outputs a drive-boosting signal to control the driving capability of the buffer 124 and adjusts the slew rate at the rising edge and the falling edge of the new special sample format signal. Thereafter, the modified special sample format signal is sent to the central processing unit 104 via the system bus interface 128. Anyone familiar with the technology may utilize the increasing or decreasing magnitude of the drive-boosting controller 126 to find the optimal drive-boosting signal.

[0051] On receiving the new special sample format signal, the central processing unit 104 asserts the next address to the system bus 128, the buffer 132 and the latching device 118. The latching device 118 outputs a result signal to the special pattern device

122. The special pattern device 122 compares the received result signals and uses the correctness of the result signals to determine if the currently set timing signal is suitable for normal operation or not. If the currently set timing result signal permits a normal operation, the phase-shifted clocking signal is chosen as a reference point. The

5 add/subtract device 106 is utilized to control the increase/decrease of the phase adjusting signal so that the phase-shifted clocking signal moves towards the left. The whole operation is repeated until the result signal received by the special pattern device 122 is in error. On returning to the reference point, the add/subtract device 106 again controls the increase/decrease of the phase adjusting signal so that the phase-shifted clocking signal

10 moves towards the right. The whole operation is repeated until the result signal received by the special pattern device 122 is in error. The separation in timing for the two result signals in error is a safe range for shifting the phase-shifted clocking signal. For example, if  $N = 3$ , the add/subtract device 106 increases the phase adjusting signal so that the phase-shifted clocking signal shifts towards the left until the phase adjusting signal is

15 increased to 4. The special pattern device 122 receives a result signal in error and then returns to the reference point. Next, the add/subtract device 106 decreases the phase adjusting signal so that the phase-shifted clocking signal shifts towards the right until the phase-shifted clocking signal is reduced to 4. The special pattern device 122 receives a result signal in error. From the aforementioned description, safety operation range for the

20 phase-shifted clocking signal can be determined to be  $-4/2^3$  of the internal clocking signal to  $4/2^3$  of the internal clocking signal. Here, 4 represents the overall phase shift value and 3 represents the phase-shift value of each phase shift. Anyone familiar with the technology may know that there are many different reference points and many phase

shifting modes for finding the safe operating range for the phase-shifted clocking signal all within the scope of this invention.

[0052] This invention also provides a timing adjustment device for adjusting the timing of data transmitted from the central processing unit to the chipset within the system bus interface 101.

[0053] In the process of adjusting the system bus interface 101, as the chipset transmits timing signals to the central processing unit 104, the core logic device 102 will assert a central processing unit reset signal to the central processing unit 104. Thus, the central processing unit 104 is restarted. After restarting, the central processing unit 104 executes special command timing signals, for example, reading an instruction from a fixed address location. The special pattern device 122 asserts a series of no operation (NOP) instruction codes during a special timing cycle under the control of the cycle protocol device 120. Since the central processing unit 104 will continue to read instructions from the next address if the NOP instruction codes are received correctly, the special pattern device 122 may compare the result signals and determine if the currently set timing permits normal operation or not.

[0054] In the process of adjusting the system bus interface 101 and as the chipset transmits data timing signals to the central processing unit 104, the cycle protocol device 120 will generate a special timing cycle simultaneously and output an expected timing signal to the special pattern device 122. On receiving the expected timing signal, the special pattern device 122 outputs a special sample format signal to the central processing unit 104 via the latching device 114, the buffer 124 and the system bus interface 101 according to the special timing cycle. On receiving the special sample format signal, the central processing unit 104 outputs the next address to the latching device 118 via the

buffer 132. For example, the cycle protocol device 120 may set the special timing cycle to be three clock cycles and the special pattern device 122 will output the special sample format signal to the latching device 114 of the system bus interface 101 every three clock cycles.

5 [0055] On the other hand, the core logic device 102 will assert an add/subtract signal to the add/subtract device 108. On receiving the add/subtract signal, the add/subtract device 108 increases/decreases a phase adjusting signal according to the add/subtract signal.

[0056] When the phase lock loop device 112 receives the phase adjusting signal  
10 and an internal clocking signal, the phase lock loop device 112 shifts the internal clocking signal according to the phase adjusting signal and a signal N. The phase lock loop device 112 then outputs a phase-shifted clocking signal to the latching device 118 of the system bus interface 101. Here, signal N is a number that decides the magnitude of phase shift in the internal clocking signal in each phase shift operation. For example, if  $N = 3$ , the phase  
15 shift value = internal clocking signal/ $2^3$ . Hence, the phase-shifted clocking signal = internal clocking signal + internal clocking signal/ $2^3$ .

[0057] The latching device 118 of the system bus interface 101 uses the phase-shifted clocking signal as a timing signal to drive out the next address from the central processing unit 104 and generate a result signal. The result signal is transferred to the  
20 special pattern device 122.

[0058] On receiving the result signal, the special pattern device 122 utilizes the correctness of the received result signal to determine if the currently set timing signal is suitable for normal operation or not. If the currently set timing result signal permits a normal operation, the phase-shifted clocking signal is chosen as a reference point. The

add/subtract device 108 is utilized to control the increase/decrease of the phase adjusting signal so that the phase-shifted clocking signal moves towards the left. The whole operation is repeated until the result signal received by the special pattern device 122 is in error. On returning to the reference point, the add/subtract device 108 again controls the increase/decrease of the phase adjusting signal so that the phase-shifted clocking signal moves towards the right. The whole operation is repeated until the result signal received by the special pattern device 122 is in error. The separation in timing for the two result signals in error is a safe operating range for the phase-shifted clocking signal. For example, if  $N = 3$ , the add/subtract device 108 increases the phase adjusting signal so that the phase-shifted clocking signal shifts towards the left until the phase adjusting signal is increased to 4. The special pattern device 122 receives a result signal in error and then returns to the reference point. Next, the add/subtract device 108 decreases the phase adjusting signal so that the phase-shifted clocking signal shifts towards the right until the phase-shifted clocking signal is reduced to 4. The special pattern device 122 receives a result signal in error. From the aforementioned description, safety operation range for the phase-shifted clocking signal is determined to be  $-4/2^3$  of the internal clocking signal to  $4/2^3$  of the internal clocking signal. Here, 4 represents the overall phase shift value and 3 represents the phase-shift value of each phase shift. Anyone familiar with the technology may know that there are many different reference points and many phase shifting modes for finding the safe operating range for the phase-shifted clocking signal all within the scope of this invention.

[0059] In the first embodiment, these devices and interfaces are housed within a control chipset. Anyone familiar with such technology also knows that these devices and

interfaces may also be considered to reside within the system bus interface of the control chipset.

[0060] Fig. 2 is a flow chart showing the steps for adjusting the timing of a system bus interface according to the first preferred embodiment of this invention. This

5 invention also provides a method of adjusting the timing of a system bus interface, where the system bus interface is coupled to the system bus and the system bus is coupled to the central processing unit.

[0061] In step S200, a central processing unit reset signal is asserted to the central processing unit. In step S202, the add/subtract control signal is used to control the

10 increase/decrease of phase adjusting signal. In step S204, the internal clocking signal is shifted according to the phase adjusting signal so that a phase-shifted clocking signal is produced. In step S206, the first special sample format signal is sent to the system bus interface according to a special timing cycle. According to the phase-shifted clocking signal, the system bus interface adjusts and drives the result signal from the system bus  
15 interface so that the second special sample format signal is produced. In step S208, the system bus interface adjusts and drives the first special sample format signal to the system bus according to the phase-shifted clocking signal. The system bus receives the second special sample format signal from the system bus interface according to the special timing cycle. In step S210, correctness of received signals is recorded. Among the  $2^N$  tests, the  
20 number of error free signals and values is found and the mid-point of these values is used as a reference. Step S210 mainly serves to determine the optimum phase-shifted clocking signal. If the optimum phase-shifted clocking signal is not yet found, step S200 is executed again so that another central processing unit reset signal and add/subtract control signal for increasing/decreasing the phase adjusting signal are asserted. The

aforementioned steps are repeated. According to the response of the signal sender and receiver, error free signal values are obtained and averaged to find the optimal phase adjusting signal for operating the system bus interface.

[0062] Fig. 3 is a schematic diagram showing a control chipset connection system

5 according to a second preferred embodiment of this invention. The control chipset connection system includes two adjustment devices 302 and 304 and two chip bus interfaces 301 and 303. In the second embodiment, the adjustment device 302 and the chip bus interface 301 belong to a north bridge control chip 300. The chip bus interface 301 is coupled to the chip bus interface 303 through a inter-chipbus. The adjustment  
10 device 304 is coupled to the chip bus interface 303. In this embodiment, the adjustment device 304 and the chip bus interface 303 belong to a south bridge control chip 350. The north bridge control chip 300 and the south bridge control chip 350 together constitute a control chipset.

[0063] The adjustment device 302 further includes two add/subtract devices 306  
15 and 308, two phase lock loop devices 310 and 312, a special pattern device 318 and a cycle protocol device 320. The special pattern device 318 is coupled to the cycle protocol device 320 and the chip bus interface 301. The phase lock loop device 310 is coupled to the add/subtract device 306 and the chip bus interface 301. The phase lock loop device 312 is coupled to the add/subtract device 308 and the chip bus interface 301.

20 [0064] The chip bus interface 301 further includes two latching devices 314 and 316, two buffers 322 and 324 and a drive-boosting controller 338. The latching device 316 is coupled to the special pattern device 318 and the phase lock loop device 312. The latching device 314 is coupled to the special pattern device 318 and the chip bus interface 303. The buffer 322 is coupled to the latching device 318 and the chip bus interface 303.

[0065] The chip bus interface 303 further includes two latching devices 332 and 330, two buffers 328 and 326 and a drive-boosting controller 339. The latching device 332 is coupled to a special pattern device 334 and the buffer 328. The latching device 330 is coupled to the special pattern device 334 and the buffer 326. The drive-boosting controller 339 is coupled to the buffer 326. The buffer 328 is coupled to the buffer 324 and the buffer 326 is coupled to the buffer 322.

[0066] The adjustment device 304 further includes the special pattern device 334 and a cycle protocol device 336. The special pattern device 334 is coupled to the cycle protocol device 336 and the latching devices 332 and the latching device 330 inside the chip bus interface 303.

[0067] The operational method is like the procedure shown in Fig. 2 for adjusting the timing of the system bus interface.

[0068] In the second embodiment, the north bridge control chip is a main control chip while the south control chip is a slave control chip. The timing adjustment device and method mainly operate on the main control chip (that is, the north control chip). However, anyone familiar with the technology knows that the south bridge can be the main control chip while the north bridge control chip can be the slave control chip. In other words, the south bridge is the target of the timing adjustment.

[0069] According to the devices and flow, a method for adjusting the timing of read-out data and the timing of write-in data is evident. Fig. 4 is a flow chart showing the steps for adjusting the control chipset connection system according to the second preferred embodiment of this invention. The timing adjustment method according to this embodiment is used for adjusting the timing of a chip bus interface of a first control chip. The chip bus interface is coupled to a bus and the bus is coupled to a second control chip.



The second control chip further includes a chip bus interface. The timing adjustment method includes the following steps.

[0070] In step S400, a phase adjusting signal is asserted. In step S402, an internal clocking signal is shifted according to the phase adjusting signal and then the phase-shifted clocking signal is output. In step S404, a first special sample format signal is sent to the chip bus interface of the first control chip according to a special timing cycle.

When the chip bus interface of the first control chip receives the phase-shifted clocking signal and the special sample format signal, step S406 is executed. In step S406, the chip bus interface of the first control chip drives the special sample format signal and outputs the signal to the chip bus interface of another chip (the second control chip) according to the phase-shifted clocking signal.

[0071] In step S408, the chip bus interface of the second control chip receives signals on the bus. The second control chip compares to check if the first special sample format signal is correctly received. Step S410 is repeated a number of times so that the phase adjusting signal is increased/decreased and output so that the optimal phase adjusting signal for operating the chip bus interface is found. In other words, the best phase-shifted clocking signal is determined in step S408. If the best phase-shifted clocking signal is not available yet, step S410 is executed again to increase/decrease phase shifting signal and the entire process is repeated until an optimum phase adjusting signal for operating the chip bus interface is obtained.

[0072] Anyone familiar with the technology may notice that the timing adjustment method may also use the chip bus interface of the second control chip according to a special timing cycle to drive the second special sample format signal to the bus. The chip bus interface of the first control chip may adjust and latch the signal on the

bus according to the phase-shifted clocking signal. The first control chip compares to determine if the second special sample format signal is correctly received. The phase adjusting signal is increased/decreased and output repeatedly a number of times so that the optimum phase adjusting signal for operating the chip bus interface is obtained.

5 [0073] Fig. 5 is a schematic diagram showing a memory controller according to a third preferred embodiment of this invention. As shown in Fig. 5, the memory controller 502 includes a timing adjustment device 506, a memory bus interface 503 and an initialization device 504.

10 [0074] The adjustment device 506 further includes two add/subtract devices 510 and 512, two phase lock loop devices 514 and 516, a special pattern device 522 and a cycle protocol device 524. The special pattern device 522 is coupled to the cycle protocol device 524 and the memory bus interface 503. The phase lock loop device 516 is coupled to the add/subtract device 512 and the memory bus interface 503. The phase lock loop device 514 is coupled to the add/subtract device 510 and the memory bus interface 503.

15 [0075] The memory bus interface 503 further includes two latching devices 518 and 520, two buffers 526 and 528 and a drive-boosting controller 530. The latching device 520 is coupled to the special pattern device 522 and the phase lock loop device 516. The latching device 518 is coupled to the special pattern device 522 and the phase lock loop device 514. The buffer 528 is coupled to the latching device 520 and the drive-boosting controller 530 and the buffer 526 is coupled to the latching device 524.

20 [0076] The initialization device 504 further includes a memory cycle initialization generator 534 and a register 532. The memory cycle initialization generator 534 is coupled to the register 532 and the memory bus 505.

[0077] On switching the system on, the memory cycle initialization generator 524 of the initialization device 504 automatically reads off data from a serial program device (SPD) inside a memory unit 508 and transfers the data to the register 532. Anyone familiar with the technology may know that this method may also be applied to a portable  
5 computer. However, because the memory addresses of the SPD are identical, a two-to-one multiplexer is needed to conduct the switching of the memory bus 505 so that SPD data from different memory locations can be stored.

[0078] The initialization device 504 sets up cycles for the memory during the initialization stage according to the data stored inside the register 532. Anyone familiar  
10 with the technology may know that these cycles are generated according to a fixed sequence based on memory specification.

[0079] After performing the initialization, timing of the signals for writing data from the memory bus interface 503 to the memory 508 is adjusted. In the process of adjusting the writing of data from the memory bus interface 503 into the memory unit 508,  
15 the cycle protocol device 524 will generate a special timing cycle and output an expected timing signal to the special pattern device 522. On receiving the expected timing signal, the special pattern device 522 outputs a special sample format signal to the latching device 520 of the memory bus interface 503 according to the special timing cycle. The special sample format signal provided by the special pattern device 522 triggers the  
20 storage of special data in a special memory address. Thereafter, the memory unit 504 is activated so that special data is output from the special memory address. For example, if the special timing cycle of the cycle protocol device 524 is set to two clock cycles, the special pattern device 522 will output special sample format signal to the latching device 520 of the memory bus interface 503 after every two timing cycles.

[0080] In the meantime, the add/subtract device 512 outputs a phase adjusting signal to the phase lock loop device 516. On receiving the phase adjusting signal and an internal clocking signal, the phase lock loop device 516 shifts the internal clocking signal according to the phase adjusting signal and a signal N and then outputs a phase-shifted clocking signal to the latching device 520 of the memory bus interface 503. The latching device 520 of the memory bus interface 503 uses the phase-shifted clocking signal as a timing signal to drive the special sample format signal and produce adjusted special sample format signal. The adjusted special sample format signal is sent to the buffer 528. Here, signal N is a number that decides the magnitude of phase shift in the internal clocking signal in each phase shift operation. For example, if  $N = 3$ , the phase shift value = internal clocking signal/ $2^3$ . Hence, the phase-shifted clocking signal = internal clocking signal + internal clocking signal/ $2^3$ .

[0081] When the buffer 528 receives the adjusted special sample format signal, the drive-boosting controller 530 outputs a drive-boosting signal to control the driving capability of the buffer 528 so that the slew rate of the rising edge and the falling edge of the new special sample format signal is adjusted. The adjusted new special sample format signal is transmitted to the memory unit 508 through the memory bus 505. Anyone familiar with the technology may utilize the increasing or decreasing magnitude of the drive-boosting controller 530 to find the optimal drive-boosting signal.

[0082] After the memory unit 508 has received the adjusted special sample format signal, the adjusted special sample format signal triggers the storage of the special data in a special memory address. Thereafter, the memory unit 508 transfers the special data in the special memory address to the special pattern device 522 via the buffer 526 and the latching device 518. Anyone familiar with the technology may know that the

latching device 518 uses the internal clocking signal as a timing signal to drive the signals on the memory bus to the special pattern device 522. For example, after the memory unit 508 has received the adjusted special sample format signal, special data FF is transferred to the memory address 3FFF. The special data FF is read out from the address 3FFF and  
5 then the special data FF is transferred to the memory bus as signals. After going through the buffer 526 and the latching device 518, the special data is converted into another special sample format signal and transferred to the special pattern device 522.

[0083] The special pattern device 522 compares the asserted special sample format signal and the received special sample format signal to find any errors and  
10 determine if the currently set timing permits a normal operation or not. If the currently set timing signal permits normal operation, the phase-shifted clocking signal is taken as a reference point. The add/subtract device 512 controls the increase/decrease of the phase adjusting signal so that the phase-shifted clocking signal shifts towards the left. The  
15 aforementioned steps are repeated until the special sample format signal received by the special pattern device 522 is in error. On returning to the reference point, the add/subtract device 512 is again utilized to control the increase/decrease of the phase adjusting signal so that the phase-shifted clocking signal shifts towards the right. The above steps are  
20 repeated until the special sample format signal received by the special pattern device 522 is again in error. The separation in timing signal between the second special sample format signals in error constitutes a safety range for shifting the phase-shifted clocking signal. For example, if  $N = 3$ , the add/subtract device 512 increases the phase adjusting signal so that the phase-shifted clocking signal shifts towards the left until the phase adjusting signal is increased to 4. The special pattern device 522 receives a special sample format signal in error and then returns to the reference point. Next, the

add/subtract device 512 decreases the phase adjusting signal so that the phase-shifted clocking signal shifts towards the right until the phase-shifted clocking signal is reduced to 4. The special pattern device 522 receives a special sample format signal in error. From the aforementioned description, safety operation range for the phase-shifted clocking signal is determined to be  $-4/2^3$  of the internal clocking signal to  $4/2^3$  of the internal clocking signal. Here, 4 represents the overall phase shift value and 3 represents the phase-shift value of each phase shift. Anyone familiar with the technology may know that there are many different reference points and many phase shifting modes for finding the safe operating range for the phase-shifted clocking signal all within the scope of this invention.

[0084] The operational method is like the procedure shown in Fig. 2 for adjusting the timing of the system bus interface.

[0085] Fig. 6 is a flow chart showing the steps for adjusting the timing of the memory controller according to the third preferred embodiment of this invention. The method for adjusting the timing signal of a memory controller includes the following steps. First, memory (not shown) is initialized so that the memory unit 508 starts to operate normally. For example, the memory initialization device 504 is used for this initialization step. In step S600, a phase adjusting signal is asserted. The phase adjusting signal is increased/decreased and re-asserted a number of times to adjust the timing signal.

In step S602, an internal clocking signal is shifted according to the phase adjusting signal and then the phase-shifted clocking signal is output. In step S604, a first special sample format signal is sent to the memory bus interface 503 according to a special timing cycle. In step S606, the memory bus interface 503 drives the first special sample format signal to the memory bus 505 according to the phase-shifted clocking signal.

[0086] The memory unit 508 sends the special data to a special memory address according to the first special sample format signal. Thereafter, the memory unit 508 is triggered to send the special data in the special memory address to the memory bus.

According to the phase-shifted clocking signal, the memory bus interface picks up signals from the memory bus to produce a second special sample format signal (not shown). In steps S608 and S610, the first special sample format signal and the second special sample format signal are compared to record any incorrect signals. The process of increasing/decreasing the phase adjusting signal and re-asserting the signal is repeated a number of times. Among the  $2^N$  tests, the number of times having error free signals is recorded. For example, using the mid-value as a principle point, the optimum phase adjusting signal or phase-shifted clocking signal for operating the memory bus interface is found.

[0087] This invention utilizes the shifting of clocking signal to rectify timing deviations due to defective chip design, CPU design, PCB layout design and SMT. Using the type of timing control provided by this invention, it is possible to integrate various devices together even if they have timing mismatch. Since there is no need to re-design the layout of circuit board or to re-fabricate bus interface due to timing mismatch, production cost and re-working time is saved.

[0088] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims and their equivalents.